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DEPARTMENT OF THE INTERIOR

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JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

PROGRESS REPORT NO. 2 ON INVESTIGATION OF DETACHABLE ROCK-DRILL BITS

BY

MCHENRY MOSIER

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By McHenry Mosier[2]

INTRODUCTION

This progress report on a national survey of the use of detachable bits in metal mines covers 10 mines. It presents comparative costs for drilling with conventional and detachable bits, describes the reconditioning of drill steel, and gives various data on rock drilling at these particular mines. Reports to follow will include similar data on drilling at other metal mines in the United States.

ACKNOWLEDGMENTS

This report is based on costs and data developed and furnished by the operators of the mines visited. The author is greatly indebted to the officials and staff members at these mines for their cooperation and assistance.

SUMMARY AND CONCLUSIONS BASED ON DATA FROM 10 MINES

In general, for the group of mines under discussion the use of detachable bits reduced the cost per foot of hole drilled. The outstanding saving made was in the cost of transporting the steel. At only one mine was the cost of drilling with detachable bits higher than that with regular drill steel. At seven mines the drilling speed of detachable bits was faster. The normal expectancy with detachable bits is for faster drilling because at mines where the gage of the finisher lies within the range for detachable bits a smaller starter can be used. This is true because smaller gage changes are possible through the adoption of the "following gage." This advantage, in turn, is peculiar to the use of detachable bits. It arises from the precision in gaging obtained at the ordinary mine shop through grinding and sorting bits as compared to forging them to predetermined standard sizes. Another contributing factor is the smaller loss in gage from abrasion with detachable bits. Again, each individual regular bit forged in mine shops is not always as perfectly formed and tempered as a detachable bit fabricated under the uniform conditions that prevail at a factory. The penetration per bit was greater for the detachable bit in six cases and less in one instance. The loss in weight of steel from all causes was reduced consistently with detachable bits. A definite increase in the efficiency of driving development headings at one mine was shown by the records to have been promoted by the use of detachable bits. This resulted in an increase in wage for the contract miners and a decrease in unit cost for the development work.

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[1] The Bureau of Mines will welcome the reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6911."

[2] Supervising engineer, metal-mining research section, mining division, U. S. Bureau of Mines.

DETAILED DRILLING DATA AND COSTS AT INDIVIDUAL MINES

Following are descriptions of rock-drill operating practice, drill-sharpening shop equipment, and routine for reconditioning drill steel and rods, together with comparative summaries of drilling performance and costs, where available, for conventional and detachable bits at individual mines.

Geneva Mine

Oliver Iron Mining Company
Ironwood, Michigan

Conclusions. - The following advantages are being derived at the Geneva mine from the adoption of the detachable bit:

1. Saving in transportation of steel between shop and working face.
2. Faster drilling speed.
3. Reduction in loss of steel from all causes.
4. More inches drilled per bit used.
5. Smaller gage loss per bit dulled.
6. Smaller stock of steel required.
7. Saving in amount of compressed air.
8. Lower total cost per foot of hole drilled.

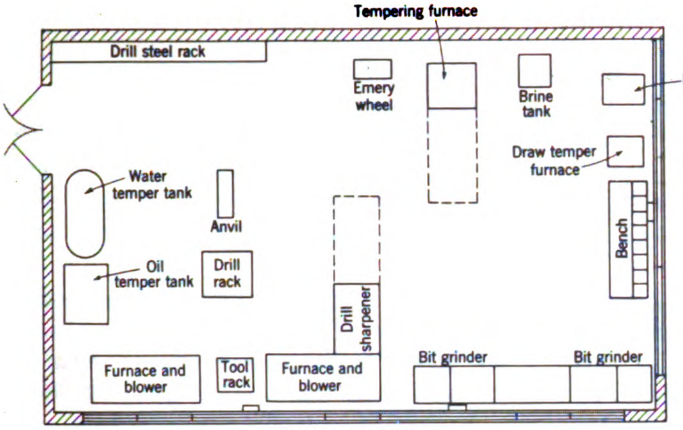
The detachable bit is also displacing auger drilling at this property.

Operating practice. - The drilling equipment comprises 4-inch drifters for use in rock work, wet jackhammers with a 2-5/8-inch bore, and wet self-rotating stopers with a 3-inch bore for work in ore. Two men are used on drifters as well as on jackhammers. The air pressure at the face is usually 85 to 90 pounds.

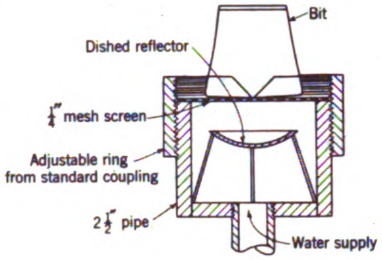
The effect of the diameter of the bit on the rate of penetration is shown in the following table.

Gage of bit	Rate of penetration (inches per minute)	Total inches drilled
2-1/2	4.93	418
2-3/8	5.33	112
2-1/4	5.69	534
2-1/8	5.64	261
2	5.82	275
1-7/8	6.48	176
1-3/4	7.78	370

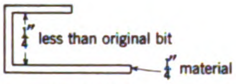
The above test was run in granite with regular drill steel of 1-1/4-inch diameter. The air pressure maintained at the drill was 90 pounds.



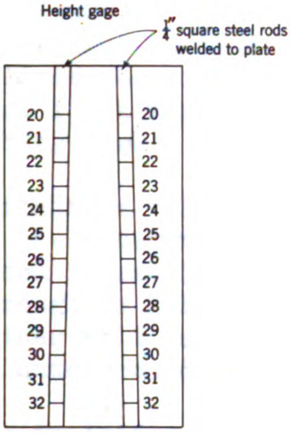
Detachable bit grinding shop
Capacity, 300 bits per shift



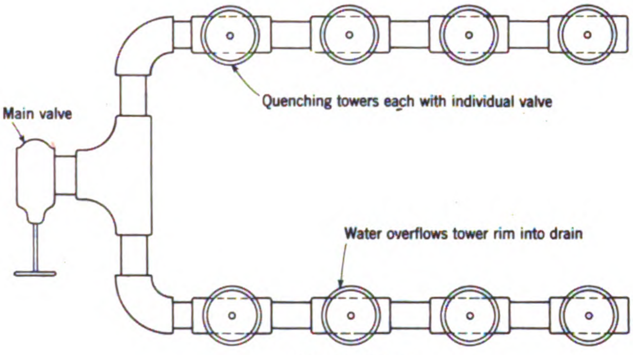
Quenching tower for individual bit



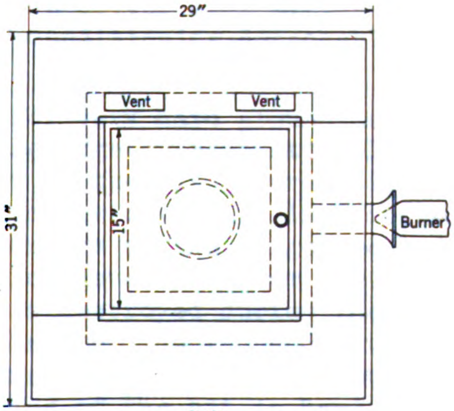
Height gage



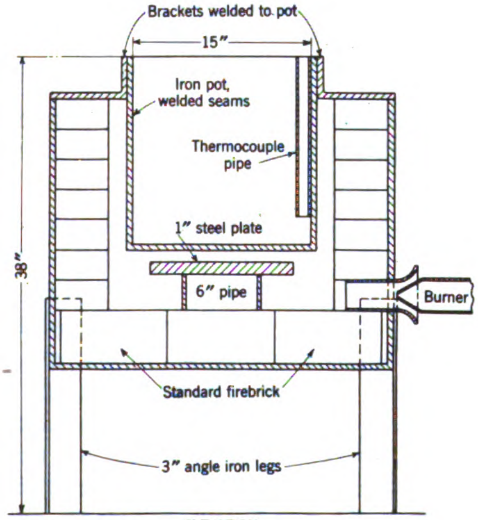
Gaging device


Main valve
Quenching towers each with individual valve
Water overflows tower rim into drain

Quenching towers



PLAN
Tempering furnace



ELEVATION
Tempering furnace

Figure 1.—Plan of detachable bit-sharpening shop and details of equipment.

While changing to detachable bits, the use of regular drill steel is diminishing gradually. In reconditioning this steel it is heated in an oil-burning furnace,using air at 10-ounce pressure. The forging is done on a standard machine sharpener. An open tank with a rising current of cold water is used for quenching the bits and a hooded oil vat for quenching shanks. This vat, with a capacity of $2\frac{1}{2}$ barrels of oil, is installed below the floor level.

The standard regular drill steel was formerly $1\frac{1}{4}$-inch hollow round but now is 1-1/8 inch. A cross bit is used with a 90° angle between cutting-edge faces and double clearance taper of 8° and 14°. The starters have a $2\frac{1}{2}$-inch gage, which is reduced by 1/8-inch changes to a finisher with 1-3/4-inch gage.

One type of detachable bit is used for hard ground and another design for soft ground.

A new drill-sharpening shop, shown in figure 1, is being constructed as an integral part of the interconnecting housing units adjoining the central shaft headframe.

The equipment to be used in the new shop consists of 2 detachable bit grinders, 1 semimuffle type tempering furnace with pyrometer and oil burner using 8 to 10 ounces air pressure maintained by small bladed fan, 1 tempering furnace (fig. 1), 1 furnace for shanks, 1 machine drill sharpener for shanks, and 2 quenching tanks.

Bit containers will be transported on small timber trucks from the shop directly to the underground tool houses on the several mine levels. Bits will then be placed in smaller containers with compartments for the various sizes and large enough to hold a shift's supply for one drill. At the end of the shift the miner will return his individual container and both sharp and dull bits to the underground tool house.

For use in drifter machines standard drill steel for detachable bits is 1-1/8-inch hollow round, but in changing from the regular drill steel the 1-1/4-inch size will be swaged down to take the bit for the standard 1-1/8-inch rod. For jackhammers, 7/8-inch hollow hexagon steel is used.

The Oliver Iron Mining Co. has developed the following standard practice for reconditioning detachable bits and rods, which is closely followed at the Geneva mine:

For very hard ground detachable bits are ground with a slightly flattened cutting edge approximating 1/16 inch in width instead of a knife edge. The center of the bit is crowned, starting on the first regrind at about 1/32 inch and increasing to 1/8 inch above the outside edge of wing on the final regrind. The corners of the wings are left rounded on about a 1/8-inch radius. This practice developed from the fact that the sharp corners on the wings of a new bit are destroyed during the first few seconds of drilling and the bit takes the shape of the rounded bottom of the hole as left by the preceding bit. The combination of the high center and rounded corners prevents "face lifting" or chipping of the bit in hard rock where gage changes are less than 1/32 inch.

Bits are not ground to standard gages but are sharpened by removing the minimum amount of metal. They are measured for gage by means of the device shown in figure 1 and are then segregated in bins by sizes to the nearest thirty-second of an inch. A 14-inch forming wheel will grind 650 bits before it need be discarded, while the gaging wheel will finish 1,000 bits. One operator can sharpen, gage, and sort approximately 150 bits per shift.

When bits are ground down about 1/4-inch below the original cutting edge, which corresponds to the depth of hardening (or the base of the martensite structure), it becomes necessary to reharden the bits if they are to be used again. This point is determined by use of a height gage shown in figure 1. The bits are heated in a semimuffle furnace for about 45 minutes at 1,450° F. They are then placed in individual bubble-spray towers for quenching. These towers are made in units of eight, as illustrated in figure 1. The bits are submerged to a depth of 3/8 inch when the water is flowing or bubbling. In quenching, the bits are left in the water until the skirt of the bit becomes black. They are then dropped into a tank of boiling water, and in 1½ hours to 2 hours they are ready for use.

After the shanks are forged on the drill rod the ends are squared by grinding on an emery wheel, and the hole is countersunk. They are then placed in the semimuffle-type furnace and heated to 1,500° F. through a distance of at least 8 inches back of the lug. This heat overlaps the forging heat. They are quenched in oil and kept submerged until cool.

On the bit end the rods are threaded on a bolt-cutting machine. For hardening they are heated in the semimuffle type furnace to 1,475° F. for 45 minutes, quenched in cold brine for 7 seconds, plunged in oil, and left to cool. They are then placed in a salt bath and tempered at 650° F. for 1¼ hours. Upon being cooled in the air they are ready for use. This tempering furnace is shown in figure 1.

Starters have a 2-inch gage and finishers a 1-5/8-inch gage. A "following" gage is used instead of predetermined gage changes.

The length of run is 24 inches maximum in rock. In soft ore, with a hand-held machine, the hole, which is usually 6 feet deep, is completed with one piece of steel. In hard ore, with a machine mounted on column or tripod, the length of run is limited to the length of the feed screw, which is 24 inches.

During the test period about 50 bits were strung on a wire for transporting from the shop to the working place and return. Suitable containers for individual miners will be provided later.

Summary of comparative drilling performance. - The following tabulation of results in drilling granite shows the comparison in the performance of the regular 1¼-inch drill steel and the detachable bits on 1¼-inch rods swaged down to take the standard bit for 1-1/8-inch rod. The formation was granite.

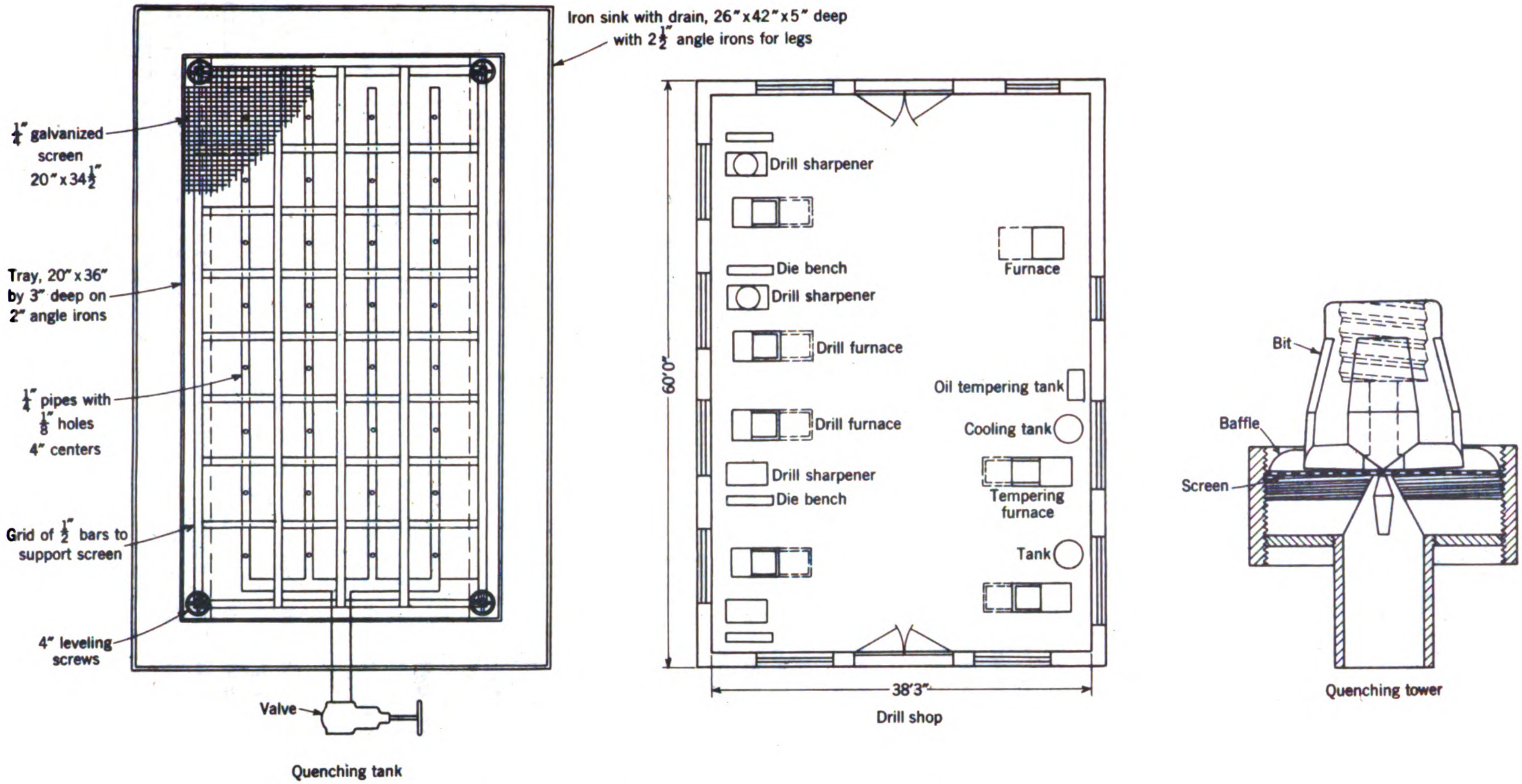


Figure 2.—Plan of drill-sharpening shop and miscellaneous details of equipment for reconditioning detachable bits.

	Regular drill-steel conventional bits	Detachable bits
Total feet drilled....................	8,476	21,932
Average drilling speed - inches per minute with 4-inch drifter	3.81	6.11
Inches drilled per bit dulled	18.49	22.48
Breakage of rods .... percent	4.2	6.0
Broken bits plus soft bits .... do.	2.4	2.6
Number of men per machine	2	2
Gage of bits used .... inches	2-3/8 to 1-3/4	2 to 1-5/8
Average loss in gage per bit used.. do.	.094	.047

The detachable bit thus shows an increase of (1) 60 percent in speed of penetration, (2) 22 percent in inches drilled, and (3) 43 percent in rod and shank breakage. The rod and shank breakage undoubtedly will be reduced after the present supply of rods converted from used drill steel is exhausted, because steel for replacements will not only be of lower carbon content but will also be from new stock.

Auxiliary tests in soft ore with a 2-5/8-inch bore jackhammer showed a speed of 21.6 inches per minute in drilling 54 feet with an auger as against 29.5 inches per minute in drilling 79 feet with a detachable side-hole bit. In fairly hard rubbly ore the regular drill steel with end hole drilled 63 feet at the rate of 15.4 inches per minute. In the same ore the detachable side-hole bit drilled 148 feet at the rate of 19.8 inches per minute.

Soudan Mine

Oliver Iron Mining Company,
Tower, Minnesota

Conclusions. - The Soudan mine is reputed to have the hardest ground of any mine in the United States. The rock in some instances is actually harder than the best rock-drill bit.

After exhaustive comparative tests over a 6-month period it was decided to displace the regular drill steel with detachable bits for all drilling throughout the mine because it was advantageous on the basis of the total cost per foot of hole.

Operating practice. - The drill-sharpening shop is near the collar of the shaft. The equipment for reconditioning the detachable bits and rods includes 4 detachable bit grinders, 1 oil-fired semimuffle furnace with pyrometer (burner uses air at 5 pounds pressure), 1 tempering furnace with thermometer, 1 oil-quenching tank, water-jacketed bottom and sides (capacity 50 gallons of oil), and 1 water-quenching tank (fig. 2).

In reconditioning detachable bits and rods the standard practice of the Oliver Iron Mining Co. is followed. This is described in detail in the section devoted to the Geneva mine. There is, however, one difference in the practice at the two mines. At Soudan after the initial quench the bits are tempered at 350° F. for 1 hour. In sharpening dull bits most of the grinding is adjacent to the cutting edges, thus increasing the angle between the cutting faces. After several such regrinds the bits are annealed, and by grinding the base of each cutting face the angle between the cutting faces is restored to the standard for new bits.

The detachable bits average eight times used. After three regrinds the bits are rehardened and then used two or three times. Some of the bits can be rehardened a second time. The average number of bits reground per man per shift is 150. The life of the 12-inch forming wheel is 1,500 bits sharpened, while that of the 12-inch gaging wheel is 1,525 bits.

Water quenching is done in a shallow iron tray supported by angle irons in an iron box or sink that stands 32 inches above the floor.

The tray is covered with 1/4-inch galvanized screen resting on a grid of solid iron bars and supported by four leveling screws. On the bottom of the tray are four parallel water pipes, 1/4 inch in diameter, spaced 4 inches apart and with 1/8-inch holes drilled at 4-inch intervals. This gives a cold-water jet rising through the screen at the corners of 4-inch squares, over each one of which a detachable bit is placed for quenching.

Summary of comparative drilling performance. - The following is a summary of comparative drilling performance.

Drilling-performance data, Soudan mine

Item	Regular drill steel, 2-1/8"-1-5/8" gage				Detachable bits, 2"-1-5/8" gage			
	Ore	Jasper	Rock	Total	Ore	Jasper	Rock	Total
Feet of holes drilled	19,222	3,364	6,680	29,266	14,821	3,186	8,490	26,497
Bits and steels used	38,312	10,360	1,012	49,684	49,971	17,343	1,930	69,244
Inches drilled per minute 1/ ..	.467	.326	1.898	-	.466	.419	2.085	-
Inches drilled per bit	6.0	3.9	79.2	-	3.6	2.2	52.8	-
Size of machine used ...inches	- -	- -	- -	3-1/2	- -	- -	- -	3
Diameter of round drill steel used ....inches	- -	- -	- -	1-1/4	- -	- -	- -	1-1/8

1/ Elapsed time.

Conditions were not entirely parallel for the tests of the two types of bits in that the gage for starters with detachable bits was 1/8 inch smaller and the bore of the machine drill 1/2 inch less than with regular drill steel. Because the smaller bore of the machine drill more than offsets the smaller gage of the bit, the circumstances in the above comparisons were to the advantage of the conventional bits on regular drill steel, and the results actually were more favorable to detachable bits than the figures indicate.

The normal footage of drilling in one year amounts to 121,750 feet. For this work there would be required 303,000 detachable bits or 224,000 pieces of regular drill steel. This corresponds to about 1,200 detachable bits or 900 pieces of regular drill steel per day. A material saving is being effected in handling steel through the shaft, on the main levels underground to development faces, and through manways to stoping faces.

In one stope the cutting speed when drilling in ore with detachable bits was observed to be 1 inch per minute. The distance drilled was 1 inch per bit. The hardest rock ever encountered while using the regular drill steel was said to have required 165 pieces of steel for one 6-foot hole.

The advantages of the detachable bit at the Soudan mine are (1) a reduction of 36.1 percent in loss of drill steel from all causes, (2) a substantial saving in transportation of drill steel, and (3) a slightly faster drilling speed.

On the basis of the cost per foot drilled, with shop costs and all other factors considered, the balance is in favor of detachable bits for this mine.

Greenwood Mine,
Inland Steel Co.
Ishpeming, Michigan

Conclusions. - The saving in cost per foot of hole drilled with detachable bits over regular drill steel, considering only shop expense, loss of steel, and transportation, amounts to 42 percent. Other economies effected by their use include the savings in labor for drilling and in the quantity of compressed air required.

Drill operating practice. - The prevailing formations in this mine are uniformly rather hard and dense. They are principally hard hematite and magnetite ore and jasper. Four-inch tappet machine drills were operating with 1¼-inch round regular drill steel, and 3-inch drills were using 1-inch hollow hexagon steel. The large machines were drilling in jasper and the small drills in ore. Starters of the cross-bit type had a 2-5/8-inch gage, while finishers had a 1-5/8-inch gage. The air pressure was 90 pounds at the compressor.

With detachable bits, 4-inch drifters and 1¼-inch round lugged steel are employed on development headings in jasper, while 3-inch tappet machines with 1-inch hollow hexagon rods are used for all work in ore. The gage of new bits purchased is 2 inches and of the discarded bits it is 1½ inches.

Shop-operating practice. - The drill-sharpening shop is at the collar of the shaft and is equipped with 1 drill-sharpening machine, 1 oil-fired muffle furnace using high-pressure air, 1 pyrometer, 1 bit-grinding machine of standard make, 1 air hammer, 1 triphammer, 1 open forge using blacksmith coal, 1 anvil, and 1 vise for upsetting bolt heads.

The machine shop, which adjoins the drill-sharpening shop, is equipped with 1 radial drill press, 1 pipe machine, 1 bolt machine, 1 power hacksaw, 1 grinder with wet and dry wheels, 1 lathe, and 1 shaper.

The bits are not ground to a definite gage but are sharpened, squared up, and sorted to a "following" gage. One man can grind about 15 bits per hour or 120 per shift. About 125 bits are sharpened per day. After three regrinds the bits are rehardened and reground twice more. This makes an average total of six uses for each bit.

In hardening detachable bits they are heated in the muffle furnace to 1,460° F. for about 1 hour. 40 to 45 bits are charged at one time. Temperature is determined by the pyrometer. The bits are quenched separately by placing each one on a screen having a 3/8-inch submergence in a current of water rising in an iron tank 2 feet in diameter. As soon as the skirt becomes black the bit is tempered by dropping it into a pail of hot water.

In making up new rods or reconditioning broken ones the steel is heated in the muffle furnace to 1,300° or even 1,400° F. and annealed in lime or mica. With the 1-inch hexagon steel it is necessary to upset one end to form sufficient stock for the threads, which are cut on a bolt machine. No upsetting is necessary on the 1¼-inch rods. The face of the rod is smoothed and squared. For hardening the rods are heated to 1,460° F., quenched in water for 7 seconds, and then quenched in oil. For tempering the rods are heated to 650° or 700° F. for 1 hour and allowed to cool in air. In hardening the shanks the steel is heated to 1,460° F. and quenched directly in oil without tempering.

Costs. - The following partial costs for detachable bits include the first cost of the bit, shop cost for reconditioning bits and rods, and loss of steel and bits.

Item	Unit cost	Cost per bit used	Cost per foot of hole
Bits:			
First cost	$0.27	$0.045	$0.031
Grinding	.05	.042	.029
Hardening	.02	.003	.002
Breakage and loss	—	.007	.005
Total bits		.097	.067
Rods:			
Loss of steel		.024	.017
Reconditioning		.030	.021
Total rods		.054	.038
Total bits and rods		.151	.105

The following tabulation shows a comparative summary of drilling performance and costs:

	Regular drill steel	Detachable bits
Total feet drilled	10,000	140,000
Inches drilled per minute with 3-inch tappet machine:		
1-1/4-inch steel	1/3.46	1/4.75
1-inch steel	(2/)	1/5.21
Inches drilled per bit dulled	3/17.3	4/17.3
Number of bits used per foot of hole	3/ 0.7	0.7
Breakage of rods at thread end in percent of times used	(2/)	1.2
Feet drilled per rod	(2/)	110 to 130
Shop expense on bits and rods plus loss of steel plus transportation, per foot drilled	$0.183	5/0.105

1/ Satterly, R. D., The Use of Detachable Drill Bits at the Greenwood Iron Mine, Inland Steel Co.: Presented at Annual Metal Mining Convention, Western Division, Am. Min. Cong., Sept. 23-27, 1935.

2/ No data available.

3/ Approximate only. Regular bits dulled to greater extent with resultant slower rate of penetration.

4/ 85 percent of drilling in hard ore with 20-inch penetration per bit and 15 percent of drilling in jasper with 2-inch penetration per bit.

5/ Includes first cost of detachable bits.

Bates Mine,
M. A. Hanna Co.

Iron River, Michigan

At the Bates mine tests with detachable bits and regular drill steel showed the following results with a 3½-inch drifter and 1¼-inch round steel:

	Regular drill steel conventional bits	Detachable bits
Formation: Hard limonite		
Total inches drilled	242	1/261
Inches drilled per minute	8.74	1/ 10.90
Number of feet drilled per bit dulled	1.68	1/ 1.82
Formation: Hard limonite		
Total inches drilled	238	2/262
Inches drilled per minute	12.13	2/ 12.93
Number of feet drilled per bit dulled	1.65	2/ 1.82
Formation: Jasper and limonite		
Total inches drilled	203	3/ 241
Inches drilled per minute	7.07	3/ 7.87
Number of feet drilled per bit dulled	1.54	3/ 1.89

1/ Originals. 2/ Second regrind. 3/ Originals and first regrinds.

The shop cost of conventional bits on regular drill steel for a 6-month period in 1935 when 25,634 bits were sharpened was 5 cents each. This cost included shop labor, steel replacement, and fuel oil but excluded compressed air, electricity, water, tools, and repairs on sharpening equipment.

For the detachable bits used on this test the average shop cost per bit dulled, including original purchase price, was 10 cents. Comparative data on all the factors involved in drilling are not as yet available.

Montreal Mine
Oglebay, Norton & Company

Montreal, Wisconsin

Conclusions. - Extended use of detachable bits at the Montreal mine since the tests from March to October 1935 indicates a trend toward a lower drilling cost per foot of hole. The universal adaptability of the side-hole pattern to the varying hardness of the material encountered, the faster drilling made possible by this type of bit, and the fact that sharp bits are always available to the miner at his working place contribute towards this cost reduction. Drilling with detachable bits is becoming general practice at this mine.

Acknowledgments.-The results of drilling tests and other data were made available through the courtesy of R. A. Angst, superintendent, and D. E. Fritz of the engineering department.

Operating practice with regular drill steel. - The central drill-sharpening shop, which is near the collar of No. 5 shaft, is equipped with 4 machine drill sharpeners with punches, 4 semimuffle type, oil-burring furnaces for forging heats, 2 semimuffle type oil-burning furnaces to heat for hardening, and 2 pyrometers.

All furnaces are fitted with hoods that are connected to exhaust fans. Individual blowers for each furnace furnish air at 5 pounds pressure. Previous to the adoption of detachable bits, about 400 pieces of regular drill steel were sharpened per day at the rate of 100 pieces per man per shift in the shop. All steel was handled in racks. (Fig. 2.)

The drill steel in service with 4-inch drifters is 1¼-inch, lugged hollow round, with 2-3/8-inch pluggers and 2-3/4-inch stopers is 7/8-inch hollow quarter-octagon. Auger steel is 1-3/4 inch with 7/8-inch solid center. All this steel has a carbon content of 0.8 percent. The 1¼-inch steel has a 10-inch run and 1/8-inch gage change, starting at 2-5/8 inches and finishing at 1½ inches. The 7/8-inch quarter-octagon steel has an 18-inch run and 1/8-inch gage change after the first change, which is 1/4 inch. Gages start at 2-1/8 inches and finish at 1½ inches.

Operating practice with detachable bits. - In addition to the above shop equipment there has been installed for detachable bits one bit grinder of standard make.

Starters are 30 inches long and carry a 2¼-inch gage bit with an 18-inch run. Bits are not ground to a definite gage change but only to a following gage. One man can sharpen and gage 120 bits per shift. The life of a sharpening wheel is 700 bit grindings and of the gaging wheel 220 bit grindings.

The steel used in the manufacture of the detachable bits has a 1.10-percent carbon content. The rods of 0.8-percent carbon content are threaded on a lathe.

In hardening detachable bits they are heated in an oil-fired furnace to 1,450° F. and quenched in water in individual towers (fig. 2) with 3/8-inch submergence until the skirt of the bit is black. They are then dropped into boiling water, where they remain for 1 hour. For hard ground they are tempered at 325° F. in tempering salts of a standard brand. After 1½ hours of this treatment the bits are cooled in air.

Shanks are heated in an oil-fired furnace to 1,500° through a length of 10 to 12 inches for 30 minutes. They are then quenched in oil and left submerged until cool.

Six inches of the thread end of the rod is heated to 1,450° F. for 45 minutes. It is quenched in brine for 7 seconds and submerged in oil until cold. It is then tempered at 750° F. for 30 minutes and cooled in air.

Operating data. - The following results of preliminary tests on development work in drilling quartz slates with a 4-inch drifter using 1¼-inch drill steel indicate that the detachable bits drilled 31 percent faster than the regular drill steel with conventional bits and they also drilled 60 percent more footage per bit.

	Conventional bits on regular drill steel	Detachable bits
Inches drilled	135	324
Inches per minute ..	8.1	10.6
Feet per bit	5.62	9.0

From tests on drilling in ore in stopes as detailed below, the net drilling speed of the detachable bit with side hole, as compared to the auger, in a hand-held machine increased from 21 to 173 percent.

	Tight sticky ore	Rubbly ore	Very tight ore
Augur (Nov. 8 to 19, 1934):			
Feet drilled	220	323	157
Drilling speed, inches per minute, actual cutting time	9½	14	6½
Detachable bit, side hole:			
Feet drilled	125	174	97
Drilling speed, inches per minute, actual cutting time	26	17	10

The regular drill steel was not used in this class of drilling in ore because of the cost of distributing the steel to working places not conveniently accessible for supplies, and the plugging of the end hole when soft rock was encountered.

In a later test of detachable bits with side hole, while drilling in ore with a hand-held machine, 402 feet were drilled at the rate of 16.44 inches per minute. For each 1/16-inch loss in gage of the bit, 10.86 feet were drilled. During the same period, using hand-held machines, 65,115 feet were drilled with augers, averaging 39.0 feet drilled per bit, and 27,098 feet were drilled with conventional end-hole bits on regular drill steel, averaging 7.2 feet per bit dulled. In this test the drilling conditions were not as severe for the augers, inasmuch as they were used exclusively in soft ground, while both conventional and detachable bits were used in ground too hard for augers to penetrate. Also, a hole in soft ground was started and finished with the same auger, regardless of gage loss, while the "run" with drill steel was limited to a loss in gage not exceeding the gage change. At present the auger steel is used only in very soft ore in stopes where wet drilling causes insecure footing and washes the ore bench away.

Vulcan Mine
Pickands, Mather & Co.

Vulcan, Michigan.

The drilling in stopes is in medium-hard ore, and in development headings it is frequently in slate or cherty iron formation.

Three and one-half inch drifters and 3-inch automatic rotating stopers are used with 1-1/4-inch hollow-round lugged steel, while 2-3/8-inch jackhammers are used with 2-1/4-inch auger steel.

Compressed-air pressure is maintained at 80 pounds at the compressor on the surface but is boosted by means of a secondary compressor underground to 100 pounds per square inch.

The shop is at the collar of an old shaft, from which the steel is transferred in an auto truck to the other shafts as needed. A four-point, end-hole bit is used on regular drill steel. It has a 90° angle between cutting faces and a double taper of 5 and 14°. The gage change is 1/8 inch with a 24-inch run.

A coke furnace heats the steel for forging and for hardening. Air is furnished by a fan blower at a pressure of about 8 ounces. High-pressure compressed air is utilized to kindle the fire. This furnace and three forges are equipped with hoods connected to an exhaust fan. There is one machine sharpener, an air hammer, and a combined shears and punch, together with emery wheels, quenching tanks, and small tools. Two men can forge and harden in one shift 250 bits on 7/8-inch steel or 200 bits on 1-1/4-inch steel or 75 augers.

In this mine one tool nipper underground with some assistance from the miners distributes and collects all the drill steel and other mining tools.

While most operations are concentrated in one area there is one remote development heading that has correspondingly high transportation costs for regular drill steel.

In a short test on detachable bits a standard-make bit grinder with 14-inch wheels was used by two men to sharpen and gage 120 bits per grinding-machine shift when grinding to 1/4-inch gage change. The indicated shop cost plus purchase price for detachable bits was greater than for conventional bits on regular drill steel. However, complete data were not yet available to show the comparative costs of all the factors making up the expense of drilling.

Calumet & Hecla Consolidated Copper Co.

Calumet, Michigan

Conclusions. - The drilling of lodes carrying native copper presents distinctive problems and difficulties. It has been found that with conventional bits on regular drill steel a small-gage, side-hole bit having the maximum possible clearance for drill cuttings gives the best results.

Preliminary tests with detachable bits, made by the Calumet & Hecla Co., indicate a slightly greater drilling speed over the conventional bits. Detachable bits drill farther per bit dulled. On early tests considerable trouble developed in extracting these drills from the holes, although no such difficulty was encountered while using conventional bits. The tendency was for copper cuttings to lodge back of the bit and to stick the drill. Small taper angles and large wing surfaces increased the difficulty. On later tests in which a bit design or pattern with greater clearance was used for the drill cuttings, this tendency was largely overcome. Further tests are contemplated.

Equipment for drilling and transportation of drill steel. - Mounted drifters with anvil blocks use 1-inch hollow hexagon steel with plain shanks. Virtually no jackhammers are in service. A spanner wrench is provided for pulling steel when necessary. A special carriage transfers drill steel through the shaft. The crew on electric tramming delivers this steel in ore cars to the several stopes, whence the miners pick it up as required.

Operating data. - A preliminary test by the company in August 1935 showed the following results:

	Conventional bits on regular drill steel	Detachable bits
Feet drilled	52.0	52.7
Number of bits used	17	10
Inches per minute, actual cutting time	8.2	8.8
Breakage of rods or shanks	0	0
Feet drilled per bit dulled	3.06	5.28
Gages ... inches	1-5/8 to 1-3/8	1-3/4 to 1-5/8
Gage change ... do.	1/16	1/16
Cost per bit sharpened ... cents	8.0	(2/)
Cost per foot of hole ... do.	1/ 2.85	(2/)

1/ Based on actual costs for a 6-month period and includes all shop expense, loss of steel from all causes, transportation on surface, through shaft, and on levels underground to foot of stopes. It does not include labor on drilling, compressed air, nor machine-drill repairs.

2/ No data available.

Champion Mine, Copper Range Co.

Painsdale, Michigan

Conclusions. - Preliminary tests with detachable bits indicate a saving on transportation of steel, a greater footage per bit used, and a higher net drilling speed based on actual cutting time. On the other hand, a little difficulty was occasionally encountered in extracting the rods and bits from the hole due to the large clearance required for drilling native copper ores. Some trouble also arose with certain types of detachable bits, owing to the high percentage of bit breakage and to the calking action of the native copper. Since the possibility of effecting a saving in drilling by the adoption of detachable bits is indicated from the results of these short tests it is proposed to obtain further data by more extensive tests.

Operating practice. - The prevailing formation underground is a hard, fine-grained, epidotized amygdaloid.

Jackhammers use 7/8-inch collared steel while drifters with anvil blocks use plain-shanked steel without lugs or collars. The average holes are drilled to a depth of 10 to 12 feet. One of the outstanding features in the drilling practice at this property is the small gage of the bit used, the starters on 1-inch hexagon steel having a gage of 1-5/8 inches. The gage change is 3/32 inch.

Shop equipment and practice. - The central drill-sharpening shop is near the collar of No. 4 shaft. The drill steel is transferred between the shaft and the shop in an auto truck.

Approximately 1,600 pieces of steel are sharpened per day. The drills are put up in iron rings holding 7 to 9 pieces each and are fastened by means of hardwood wedges. The ring is stamped with the same number as the machine in which the steel is to be used. At the shop an overhead crawl and air-cylinder lift facilitates handling these bundles. After the steel has been racked according to lengths, it is heated in two oil furnaces using 12-pound air from a reducing valve on the compressed-air line. The drills are placed in the cool end of the furnace and, by means of a sprocket and chain carrier, they are gradually moved to the hot end of the furnace. The temperature is controlled by means of pyrometers. The forging heat is 1,750° F. The oil consumption for each furnace is 30 to 40 gallons per shift. The drills are forged in a battery of six machine sharpeners. Gages are checked by means of a steel plate through which holes are bored to the proper diameters. The drills are reheated for hardening in two oil-fired furnaces using 9-pound air. A temperature of 1,450° F is determined by pyrometers. These furnaces each burn 15 gallons of oil per shift. The critical temperature of the steel is checked by a magnet. The bits are quenched in water rising in a 2- by 2- by 8-foot trough. Jackhammer shanks, after being heated in a coke furnace, are collared in a bolt machine. They are then reheated and quenched in oil in a 20- by 36- by 60-inch tank, which is water-jacketed on the sides.

Operating data. - Preliminary tests made in December 1934 with detachable side-hole bits and regular drill steel with end-hole conventional bits gave the results shown below. These figures are indicative of the trend only, inasmuch as the base line is very short and only a few of the factors that enter into the cost of drilling are used in the calculations. Detachable-bit breakage on one test was excessive and thus vitiated otherwise favorable results. A bit of another pattern designed to overcome this breakage is being considered for additional tests.

	Conventional bits on regular drill steel	Detachable bits: test -		
		A	B	C
Feet drilled	103.3	131.6	100.9	160.9
Number bits used	42	47	37	30
Feet drilled per bit dulled	2.46	2.8	2.95	5.4
Number of regrinds	-	2	2	2
Gage .... inches	1-7/16 to 1-1/4	1-7/8 to 1-9/16		
Drilling speed, actual cutting time .... inches/minute	10.0	9.4	10.4	x
Plugged bits	6	0	0	0
Shop cost plus purchase price:				
Per bit used .... cents	10.0	11.1	8.4	11.0
Per foot of hole .... do.	4.1	4.0	2.8	2.0

Homestake Mine

Homestake Gold Mining Co.
Lead, South Dakota

Conclusions. - Preliminary tests with detachable bits at the Homestake mine resulted in approximately the same drilling speed and the same number of feet drilled per bit as with regular drill steel. The indicated cost per foot, considering the first cost of drill steel and detachable bits, transportation, and distribution of drill steel, shop expense, steel loss, drill-operating labor, and compressed air, is materially less with regular drill steel than with detachable bits.

Operating practice. - In general, the rock drilled is dense, hard, siliceous, and abrasive.

All machine drills are of the anvil-block type, using plain shanks on the steel. Drifters have diameters of 3, 3¼, and 3½ inches; pluggers and jackhammers, 2-1/8 to 3 inches; and stopers, 2-1/8 to 3 inches. There is one man per machine shift. Air pressure at the compressor is 100 pounds, with little drop from this at the machine. About 150 feet are drilled per machine in drifts and raises. In stopes, owing to the necessity of other work for the miner, including barring down, the effective drilling time is about 3-1/2 hours per shift. In this period three 10-foot holes, or 30 feet, are generally drilled. Holes average 7 feet in depth in development and 10 feet in stopes. The drilling speed with a 3-1/2-inch drifter in average good drilling ground is 12 inches per minute with a 1-5/8-inch bit. In this ground a bit will drill 24 inches, but in the hardest rock a single bit may have a life of only 2 inches. Gage loss is approximately 1/8 inch per bit dulled.

The drill-sharpening shop is located at the supply shaft, where all drill steel is lowered into the mine. The equipment consists of 11 sharpening machines of local design, 6 gas-fired furnaces with double openings, using gas at 9-1/2 pounds pressure and air at 7-ounce pressure, 1 blower for low-pressure air, 1 drill-steel straightener, piston type, 1 shank grinder of local design, 1 countersinking device, 1 air hammer converted from piston drill, 1 forge, anvil, and various small tools, 1 water-quenching tank 3- by 8- by 1-1/2-feet, 1 oil-quenching tank 3-1/2 by 6-1/2 by 1-2/3-feet with rack at top for draining drill steel, 2 two-wheeled, flat-tread trucks, and special drill-steel trucks with bed 4 feet long and 15 inches above rail and with short, flaring sides and 4 low vertical standards.

The general arrangement of the shop is shown in figure 3. The dull drill steel delivered from the mine in the special trucks mentioned above is sorted by lengths and placed in steel racks. The differential in length of racks is 1 foot. The measurement of the drill steel is made by means of a horizontal bar placed at the correct height above the floor at each rack. The sharp steel is handled in a similar manner in its own racks. The number of bars of dull steel of each length is recorded for each truck and an even exchange of sharp steel is made.

One-inch quarter-octagon drill steel with 1/4-inch hole is standard for all drills. Bits for drifters and stopers are four point, having an angle between cutting edge faces of 90° and clearance tapers of 3° and 15°. Starters have a 2-1/2-inch gage and are 2-1/2 feet in maximum length. Gage reduction is 1/8 inch per linear foot or 1/4 inch on a 2-foot run. Finishers are 10-1/2 feet long with a gage of 1-1/2 inches. In assembling his set of drill steel the miner selects lengths either in even feet or in odd feet. This arrangement is advantageous in that it balances to better advantage the reduction in the lengths of the steel due to drilling and sharpening. None of the bits has full reaming edges. The bits on jackhammer drill steel have six points with single clearance taper of 9°. These drills, which are used entirely for block-holing, have a gage of 1-1/2 inches and a maximum length of 2-1/2 feet.

The forging temperature is estimated to be 1,900° F. Forging is done under a light air hammer built in the sharpener. A punch is incorporated in the sharpening dolly. The jackhammer bits are reheated and finished on a separate sharpening machine equipped with oversize dollies to remove the fins from the face of the bit. By virtue of operating a large number of sharpening machines a routine has been developed of allocating a certain length of steel to each sharpening machine, thus eliminating the necessity of changing dies and dollies. For hardening bits are reheated to 1,500° F. before quenching in water.

All shanks are plain and unforged. After their ends are ground on an emery wheel they are squared on a shank grinder. Their edges are then beveled and the center holes countersunk. On reheating to an estimated 1,500° F. they are hardened by quenching in oil, which is cooled by blowing compressed air through it.

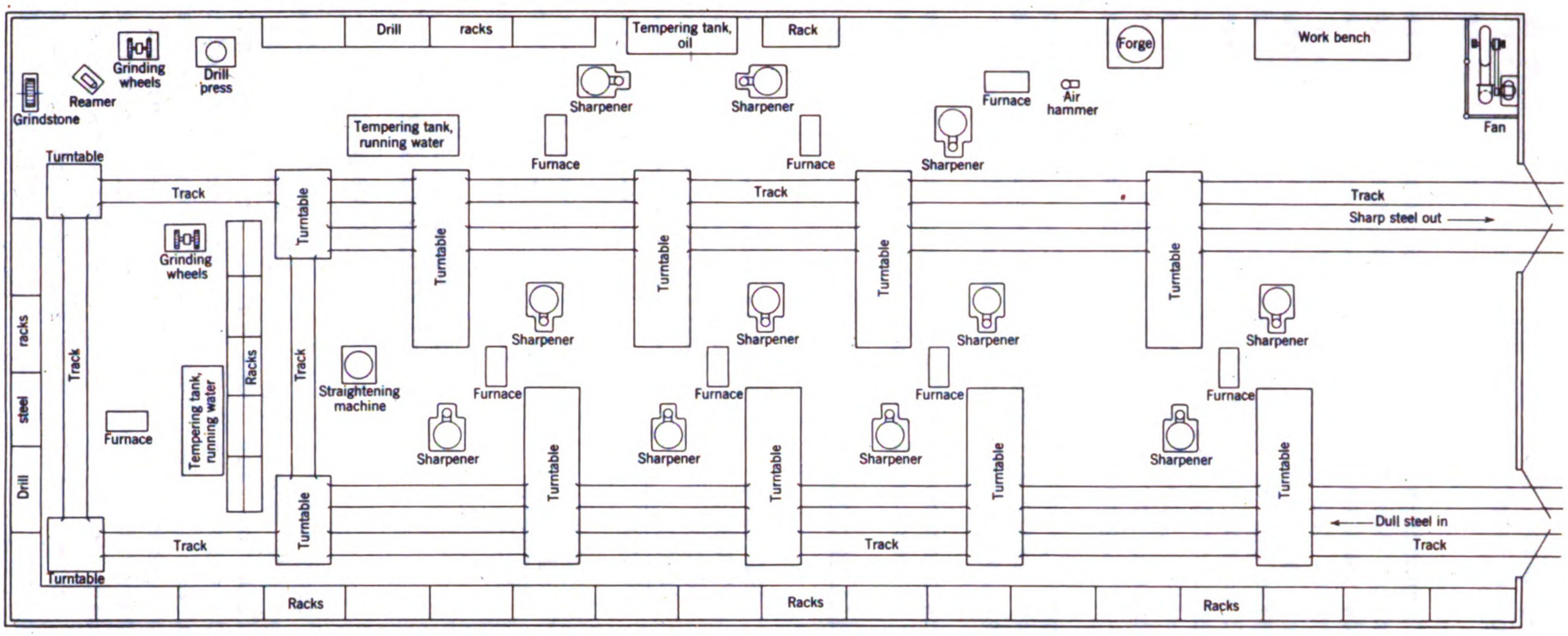


Figure 3.—Plan of drill-sharpening shop.

During the year 1935 over 1 million pieces of drill steel were sharpened, which is at the rate of 3,325 pieces per working day. This is equivalent to 300 pieces per sharpening-machine shift.

The special drill-steel cars mentioned under shop equipment convey the drill steel from the shop on the cage through the shaft and on the mine levels to development faces and to racks at convenient locations near stopes. At the stope raises the miners operate air hoists for hoisting and lowering steel buckets or skips fabricated from 3/16-inch iron. These skips are 5 feet long and 10 inches wide, with sloping sides 15 inches deep at the bottom and 4 inches deep at the top. They are fastened to the cable through chains from ears welded to the sides. A retaining chain about midsection is used to lash the steel to the skip. Nippers, each of whom serves one or more levels, collect the dull steel and return it to the nearest drill-steel rack on the tramming level, where they load it on steel trucks for transportation to the shop.

The breakage of cross bits on regular drill steel is 4.3 percent and the corresponding shank breakage is 3.6 percent, making the total breakage 7.9 percent. The total bit and shank breakage of jackhammer steel is 1.3 percent.

Costs. - The cost of sharpening conventional bits on regular drill steel is shown below, including labor, fuel, and steel replacement:

Shop cost	Cost per bit
Labor:	
Sharpening	$0.02120
Tempering	.00678
Grinding	.00156
Handling	.00846
Total	.03800
Gas (fuel)	.0041
Steel replacement	.0147
Total	.0568

Cliffs-Shaft Mine
Cleveland-Cliffs Iron Co.

Ishpeming, Michigan

Conclusions. - A saving has been effected in the total cost per foot of hole drilled by the use of detachable bits largely through the reduction in drill-steel transportation expense and in the labor cost for drilling. Steel distribution underground has been an important item of expense at this mine on account of (1) the large area covered by mine openings, (2) the use of intermediate levels, and (3) the driving of many raises. Likewise, because of the hard rock universally encountered in both stoping and development, a great many pieces of regular drill steel were required daily. Although these were bundled in sets to facilitate handling, yet they had to be placed in the skip for transportation through the shaft with attendant interruption in ore hoisting. Due largely to a reduction in size of the starters the cutting speed of drills was increased, with resultant lower labor cost for drilling. The gage of the starters used with conventional bits was 2-9/16 inches, while of the starters used with detachable bits was either 2 or 2-1/8 inches. Furthermore, a saving in powder consumption has been effected by drilling a smaller hole.

Shop equipment for regular drill steel. - In the central shop for sharpening regular drill steel, which is located at the Cliffs shaft, the equipment comprises 2 sharpening machines, 1 oil-burning furnace using 15-pound air for heating bits, 1 oil-burning furnace for heating shanks (compressed air, by blowing through perforated pipe, cools ends of shanks and prevents upsetting while forging lugs), 1 tempering furnace with oil burner, 1 water-quenching tank (2-1/2 by 7 by 2 feet) with rising current of water and punched plate shelf for supporting drills, 1 power hacksaw, 1 oil-quenching tank with a capacity of half a drum of oil, 1 double emery wheel, and 1 175-pound anvil.

The steel used is 1-1/4-inch hollow round lugged for drifters, 1-1/8-inch hollow hexagon, and 1-1/4-inch hollow hexagon for anvil block machines. It is placed in racks in the shop and segregated by mine contract numbers, which are stamped on the steel.

Two men sharpen 250 bits per day in addition to performing other duties.

Shop equipment and operating practice for detachable bits. - The shop for reconditioning detachable bits is also at the Cleveland Cliffs shaft and is equipped with 4 grinding machines, 1 electric muffle furnace with pyrometer, 1 water-quenching tank, and 1 oil-quenching tank.

The grinding machines are standard make and use 14-inch wheels. The electric furnace is rated at 26 kw., with a maximum temperature of 1,850° F. The pyrometer shows actual temperatures on a dial with an indicating hand. The water-quenching tank is of steel and 10 inches deep. Apertures in the steel cover plate, spaced at the corners of 6-inch squares, center the bits vertically above the 1/2-inch water jets rising from a manifold at the bottom of the tank. A screen shelf near the top of the tank can be adjusted so that the bits may be submerged at any depth. The oil-quenching tank, which is water-jacketed on sides and bottom, has a capacity of 3 barrels of oil.

The new bits purchased are 2-1/8- and 2-inch gage. A 2-inch bit can be reground six times. The bit is rehardened when its gage has lost 1/4 inch, which is usually after three regrinds. Before rehardening, bits are annealed and ground. They are discarded when reduced to 1-5/8-inch gage. Three men sharpen and gage a total of 450 bits per day. After the bits are sharpened, the gage is measured and they are sorted to the nearest 1/32 inch. There is a slight crowning on the first regrind. On the second regrind the crowning measures 1/16 inch. In some instances the corners of the wings are also slightly beveled.

Seventy-five bits in one charge are heated for 1 hour in the electric furnace at a temperature of 1,500° F. A little charcoal is sprinkled in the front end of the muffle to maintain a reducing atmosphere. After 12 bits have been removed the furnace door is lowered and the temperature checked before the next lot is removed. In the water-quenching tank the bits are submerged about 3/4 inch.

As soon as the shell turns black the bits are thrown into a tank of boiling water, where they remain 1/2 hour to temper them and to prevent chipping of the faces of the bits.

The rods are threaded in a bolt cutter equipped with a special set of thread-cutting dies. This machine is reserved exclusively for cutting threads on rods for detachable bits. By means of this arrangement the setting of the dies is not changed, and the work done is extremely accurate. The thread end is then heated to 1,510° F. for 45 minutes, quenched in water for 7 seconds, then quenched in oil until cool. For tempering they are again heated in the electric furnace to 650° F. for 1-1/2 hours, then cooled in air. The shank end, after being forged at 1,900° F., is subjected to the same heat treatment as the thread end for hardening except that the quenching is entirely in oil and there is no tempering.

Operating data. - Through the courtesy of C. J. Stakel, superintendent, the following examples of operating data are furnished.

A. Formation: Hard hematite ore (hard steel ore).
Operation: Drifting.

	Regular drill steel, conventional bit	Detachable bit
Number of feet drilled	29.17	27.62
Inches drilled per minute (cutting time)	1.77	2.90
Inches drilled per bit dulled	8.99	10.35
Number of bits per foot of hole	1.33	1.16
Gage of bit .... inches	2-9/16 to 1-5/8	2
Size of machine drill .... do.	3-1/2	3-1/2

B. Formation: Cherty, abrasive, siderite ore.
Operation: Drifting.

	Regular drill steel, conventional bit	Detachable bit
Number of feet drilled	19.79	36.58
Inches drilled per minute (cutting time)	1.69	2.98
Inches drilled per bit dulled	7.91	9.15
Number of bits per foot of hole.........	1.51	1.32
Gage of bit .... inches	2-9/16 to 1-5/8	2
Size of machine drill .... do.	3-1/2	3-1/2

In mining it occasionally happens that an increase in efficiency may be effected in one portion or phase of a major process at the expense of some other portion, so that the over-all efficiency and costs remain the same. In this instance, however, the gain in drilling speed is reflected in greater efficiency in both development and mining. Comparative figures show that progress of development headings has increased and development costs have decreased with the introduction of detachable bits. The following typical examples were taken from the record of development costs. These were selected to show headings in which the formation and other operating conditions were virtually identical for both conventional and detachable bits.

Location	Formation	Item	Regular drill steel	Detachable bit
I. 10' x 10' motor drift	Alternating siderite and diorite.	Feet advance in heading per miner per shift	1.90	2.62
		Cost per foot, drilling labor plus explosives	100%	85%
		Average daily wage	100%	120%
		Length of period in months ..	6	5
II. 7' x 7' raise.	Siderite	Feet advance in heading per miner per shift	1.55	2.09
		Cost per foot, drilling labor plus explosives	100%	72%
		Average daily wage	100%	111%
		Length of period in months ..	6	4
III. 8' x 8' motor drift	Siderite	Feet advance in heading per miner per shift	1.55	2.29
		Cost per foot, drilling labor plus explosives	100%	90%
		Average daily wage	100%	118%
		Length of period in months ..	4	5
IV. 10' x 10' motor drift	Siderite and diorite	Feet advance in heading per miner per shift	0.93	2.22
		Cost per foot, drilling labor plus explosives	100%	61%
		Average daily wage	100%	121%
		Length of period in months ..	6	3
V. 8' x 8' motor drift	Siderite and hematite (steel ore).	Feet advance in heading per miner per shift	0.93	1.65
		Cost per foot, drilling labor plus explosives	100%	69%
		Average daily wage	100%	116%
		Length of period in months ..	6	4